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Modification of geometry of airfoil NACA 0018 towards work testing vertical axis wind type Darrieus Eggbeater

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Abstract. Technological developments on energy savings are caused by increasing demand for energy use from year to year. This is done to avoid an energy crisis. The energy crisis is a problem that is being faced because of the depletion of fossil energy. To restore fossil energy can require natural processes in a long time. With the limited availability of fossil energy, it is very necessary to develop alternative energy sources that are friendly to the environment, one of which is wind energy. Indonesia is an archipelago, so the wind speed in Indonesia is relatively low, then in this study can be overcome using a vertical axis wind turbine (VAWT). This research was conducted to find out power of Coefficient, type speed ratio in the variation of wind speed in the turbine. This study uses a wind power design with a vertical axis. Blades are used from modified NACA 0018 airfoil. Research result taken at the time of testing is with wind speeds ranging from 3 m / s to 6,1 m/s which measures the capacity of electric power produced by turbines with a load of 10 watts. The results of this study are the minimum actual power of the turbine 2.881 Watt with TSR 0.4 and Cp 0.18 at wind speed 3 m/s, and the maximum power obtained at a speed of 6,1m/s that is equal to 14.62 Watt with a TSR of 0.25 and Cp of 0.29.

1. Introduction

Along with technology development, the increased demand on use of energy to the inhabitants of a country from year to year, especially in electrical energy. This electrical energy is a very important basic human need where every human being is very dependent on electricity for their daily needs [1,2]. From the crisis of fossil energy, renewable energy can be developed, one of the renewable energy that is easily developed is wind turbines by utilizing wind energy that blows. Because wind is one of the energy resources that will never run out by utilizing the wind can convert kinetic energy from wind into electrical energy obtained from the spin generator. For now Indonesia, especially wind energy has begun to pay attention to improve the efficiency of electricity generation [3]. The planned turbine type is a vertical axis wind turbine (VAWT) type Darrieus Eggbeater by modifying the Naca 0018 airfoil. The blade rotor on the wind turbine aerodynamically must produce optimum efficiency to maximize the mechanical power that is converted from wind kinetic energy. The aim of this research is to become one of the references for developing small-scale turbines that can be applied in urban environments with a household scale, and for villages that have fairly low wind speeds and Analyze the performance of vertical wind turbines, namely Darrieus wind turbines by modifying the Naca 0018 airfoil By doing this research, hopefully it can provide positive benefits for the development of alternative energy utilization in Indonesia.

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2. Theory

2.1. The power of wind
Kinetic energy obtained from the wind is converted into electrical energy with wind turbine facilities. Wind that has mass (m) and velocity (v) will produce kinetic energy of [4]:

$$E_k = \frac{1}{2}\, m\, v^2 \tag{1}$$

Wind energy is the power (Watt) generated from each area, so that wind power can be classified as potential energy. The volume of air per unit time (discharge) that moves with velocity v and passes through an area of A is [4]:

$$P_w = \frac{1}{2}(\rho A v)(v^2) = \frac{1}{2}\rho A v^3 \tag{2}$$

Where:
P_w = The Power of Wind(Watt) A = Cross-sectional area (m^2)
ρ = wind densitas (ρ = 1.2 kg/m^3) v = wind velocity (m/s)

2.2. Turbine power
To calculate the turbine power generated by a generator that has been connected to the turbine, that is by the following equation [5].

$$P = \mathrm{V.I} \tag{3}$$

Where:
V = voltage (V) I = Current (A)

2.3. Coefficient Performance (CP)
Coefficient Performance or often also called efficiency. Power obtained by wind turbines. P (power) and Pw (wind energy) by entering the equation, then Cp can be obtained [4].

$$Cp = \frac{P}{P_w} \tag{4}$$

2.4. Tip Speed Ratio (TSR)
Tip speed ratio (TSR) is the ratio between turbine rotation and wind speed. TSR is symbolized by λ formulation can be written as follows in Da Rossa [4].

$$TSR = \frac{2\pi n R}{60 v_w} \tag{5}$$

Where:
λ = tip speed ratio (TSR) n = putaran poros (rpm)
ω = the angular velocity(rad/s) v_w= the wind velocity (m/s)
R = Turbine Radius (m)

Each type of wind turbine has different characteristics and therefore the power factor as a TSR function is also different as shown in the Figure 1.

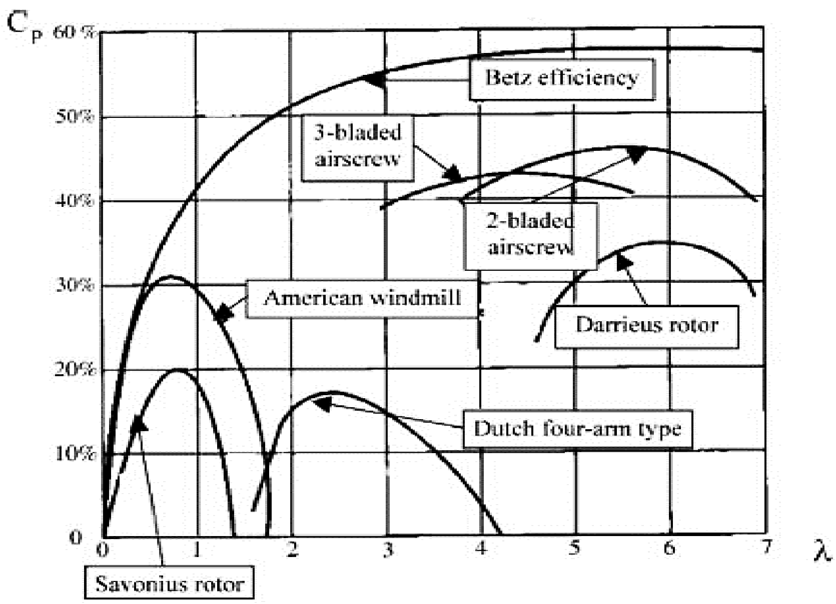

Figure 1. Type of wind turbine.

2.5. Actual torque

Torque is a force that is able to produce rotation of a rotating axis or multiplication vector between the distance of the rotary axis with the power acting at a point that is distance from the central axis. Then it can be formulated as below [4].

$$T = F\,r \quad (6)$$

In a large wind turbine, the torque obtained depends on the wind speed in the turbine, the turbine power generated is connected with the torque angular velocity. It can be formulated as below.

$$P = T\,\omega \qquad => \quad T = P/\omega \quad (7)$$

The angular velocity (ω) is formulated as follows (Vaughn, 2014).

$$\omega = \frac{2\pi n}{60} \quad (8)$$

Where:
T = torque produced from shaft rotation (Nm)
F = the force acting on the shaft (N)
r = spacing arm spacing (m)

3. Methodology

This earlier study designed the Darrieus Eggbeater turbine by modifying the cross-section using the NACA 0018 airfoil. To complete this research, a flow chart that drew a comprehensive picture of the stages was carried out as follows (see Figure 2).

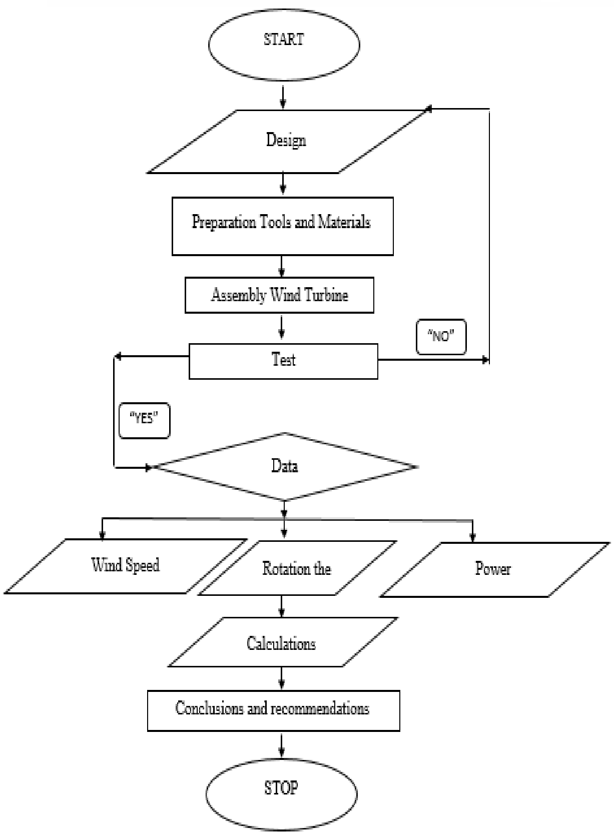

Figure 2. Flow chart.

Turbine design and specifications can be seen in Figure 3, Figure 4 and Table 1.

Table 1. The planned turbine model.

Material	fiberglass	Shaft Diameter	30 cm
Chord Length	27 cm	Shaft Length	200 cm
Length	100 cm	Radial Circuit	60 cm
Wide	13 cm	Number of Blades	3
weight 1 sudu	1.5 kg		

The following is the design of the designed blade (see Figure 3).

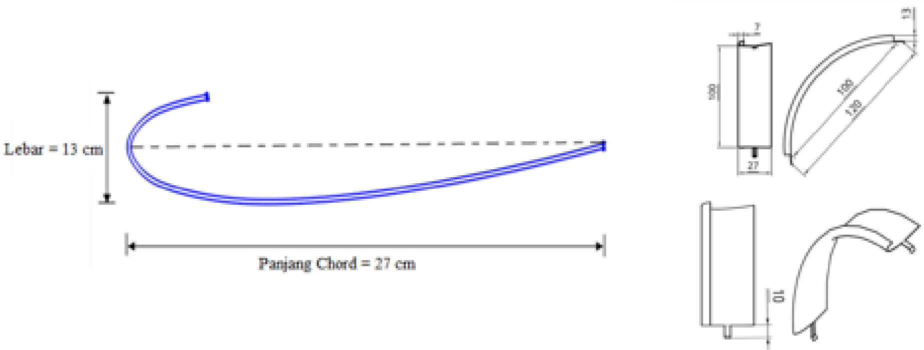

Figure 3. Designed blade.

Figure 4. Turbine designed.

4. Results

The place of this research is in the Energy Conversion Laboratory, Mechanical Engineering, Faculty of Engineering, Indonesian Christian University and the time of this research is starting from March 2020 to June 2020. And from the data from the test results can be used to see the comparison between wind speed and power actual turbine. The test is carried out three times when testing is used by using a 10 watt DC lamp range, from the third test data to perform data processing, then from the three presentations the average data is searched, while the average test results can be made as a table 2.

Table 2. Test average.

Wind velocity (m/s)	Shaft Rotation (rpm)	Voltage (Volt)	Current (A)
3	19	6.64	0.4
4	20.5	7.59	0.86
5.2	21.8	8.2	1.25
6.1	25	8.7	1.73

After processing the data from the test results table with the formulas used, the results of the data processing can be made into a table as follows. Calculations can be used data from table 2. The following is an example of a calculation used.

Wind power (theoretical)

$$P_w = \frac{1}{2}\rho A v^3 = \frac{1}{2} \times 1{,}2\ kg/m^3 \times 0{,}99 m^2\ \times (3 m/s)^3 = \text{ 16.038 Watt}$$

Turbine power (generator)

$$P_{out} \quad = V \times I\ = 6.7 \times 0.43 = 2.881\ Watt$$

CP/ η

$$\mathrm{Cp} = \frac{\mathrm{P}}{\mathrm{P_w}} \times 100\ \% = \frac{2.881}{16.038} \times 100\ \%\ = 18\ \%$$

Tip speed ratio

$$\mathrm{TSR} = \frac{2\pi n R}{60 v_w} = \frac{2\times 3.14\times 19.2\times 0.6}{60\times 3}\ = 0.40$$

Torsi Actual

$$P = T\ \omega$$
$$\mathrm{T} = P/\omega$$

$$\omega = \frac{2\pi n}{60}$$

$$T_{act} = \frac{2.881\ j/s}{2\ rad/s}$$

$$T_{act} = 1.44\ Nm$$

The following is a table of data processing results from all data from the test results that have been done (see Table 3).

Table 3. Processing results.

Wind velocity (m/s)	Shaft Rotation (Rpm)	Generator rotation (Rpm)	Volt (V)	I (A)	P_w (Watt)	P_{out} (Watt)	Tsr	Cp (%)	Torsi (N.m)
3	19.2	138.6	6.7	0.4 3	16.038	2.881	0.40	18	1.44
4	20.7	149.5	7.6	0.8	38	6.08	0.32	16	2.9
5.2	21.9	158.1	8.2	1.2	83.5	9.84	0.27	12	4.29
6.1	24.5	176.9	8.6	1.7	134.8	14.62	0.25	11	5.71

From the results of data processing which can be where the results of processing can be described in graphical form.

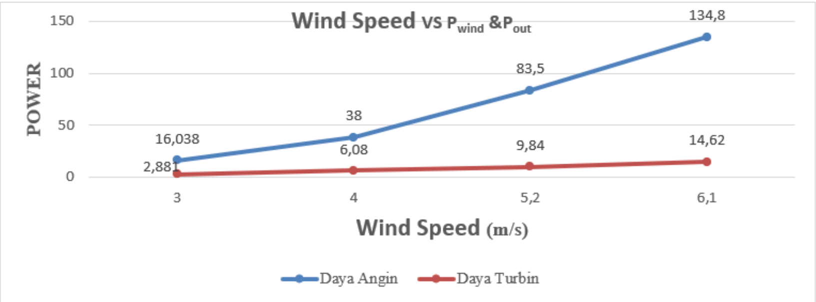

Figure 5. Graph of relationship between wind speed and wind power and turbine power.

Based on Figure 5 can be seen the relationship between wind speed is directly proportional to the theoretical power produced. Where the higher the wind speed, the higher the theoretical power is produced. Vice versa if the lower the wind speed, the theoretical power produced is also lower and the magnitude of the wind speed is closely related to the rotation of the turbine shaft to produce the magnitude of the generator rotation where the greater the rotation of the generator, the power generated is also greater. From the graph above the actual power generated at 3m/s wind speed is 2,881 Watt while the theoretical power is 16.038 Wat, at 4m/s actual power speed is 6.08 Watt while the theoretical power is 38 Watt at wind speed 5.3m/s actual power 9.84 Watt while the theoretical power is 83.5 Watt and at wind speed 6.1 m/s the actual power obtained is 14.62 Watt while the theoretical power is 134.8 watts. From the power produced by the turbine in this research, the greatest power is at 6.1 m/s with a power of 14.62 Watt and the smallest power at a speed of 3 m/s with the power generated at 2,881 Watt.

Figure 6 shows that the smaller the TSR value, the Coefficient of performance value decreases, but in this study conducted experimentally there is a decrease in TSR. The decrease in TRS and CP occurs because wind energy with high wind speed is not able to convert wind energy into mechanical energy in the turbine through the shaft rotation because the wind speed in the area behind the turbine or when crossing the turbine is fast enough so that when the turbine blade rotates a little it is blocked with its turbine efficiency also decreases.

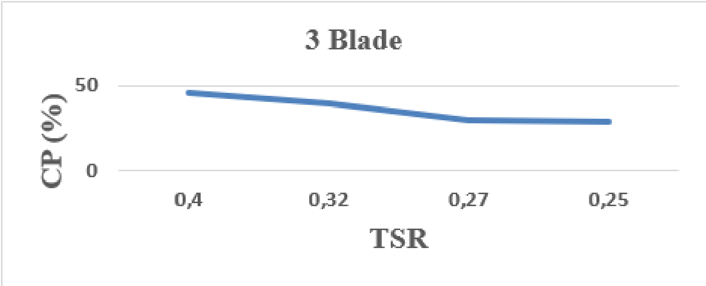

Figure 6. Comparison graph between CP (Coefficient of performance) and TSR (Tip Speed Ratio).

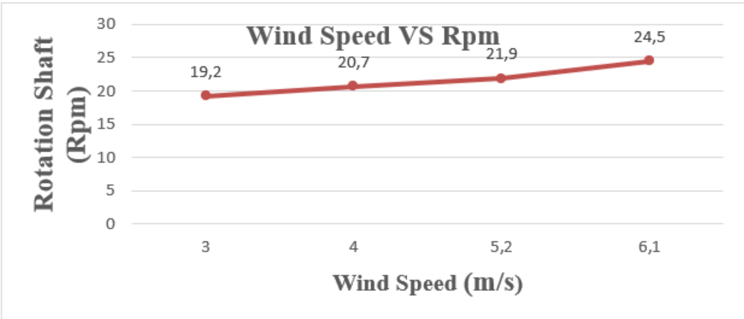

Figure 7. Graphic relationship between wind speed with turbine rotation.

From Figure 7, can be seen in this study where the greater the wind speed, the greater the rotation of the shaft produced or can be said to be directly proportional. The highest shaft rotation can be at a wind speed of 6.1 m / s with a shaft rotation of 24.5 rpm.

5. Conclusion

Based on the calculation and manufacture of wind turbines that have been done by utilizing wind energy as a wind power plant, the writer can make a conclusion that the results of this test can produce a maximum theoretical power that gets 53.1 Watts and a maximum actual power of 14.64 Watt at speed the wind that is given 6.1 m / s, the highest Coefficient of performance (%) in the tests conducted is 45% when the wind speed is given 3 m / s and the highest Tip Speed Ratio in the tests conducted is equal to 0.4 when the wind is given a speed of 3 m / s.

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